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ABSTRACT

A study investigated whether readers infer automatically highly likely consequences of a state modification, intentional (action) or non intentional (event), described in short texts. Subjects, 48 psychology undergraduates at Paris VIII University (France), read explicit, predictable, or control forms of short passages using a Rapid Serial Visual Presentation procedure, after which they answered a question about the sentence and made a lexical decision. The lexical decision task used two SOAs (Stimulus Onset Asynchrony): 400 ms and 800 ms. Results indicated that: (1) accuracy on the comprehension questions was 95% overall and did not vary as a function of condition; (2) the explicit condition produced a faster response than the predictive condition that, in turn, produced faster responses than the control condition; (3) the long SOA produced faster responses than the short SOA; (4) causal inference began to decline with a SOA equal to 800 ms; and (5) the decision latencies of inferences expressed by an action were significantly faster than the decision latencies of inferences expressed by an event. Findings suggest that inference about the likely consequences of events and actions are drawn while reading. (Contains 13 references. Appendixes present examples of sentences and final activation values of the propositions of the text base of the three forms of one of the passages.) (RS)

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AUTOMATIC AND STRATEGIC ASPECTS OF INFERENCE PROCESSING DURING COMPREHENSION: THE CASE OF PREDICTABLE CONSEQUENCES OF EVENTS AND ACTIONS

by

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Automatic and strategic aspects of inference processing during comprehension:
The case of predictable consequences of events and actions.

Objectives

This research asked whether readers infer automatically highly likely consequences of a state modification, intentional (action) or non intentional (event), described in short texts. If recent studies showed that people draw bridging inferences necessary to establish causal coherence (Keenan, Baillet, & Brown, 1984; Singer, Halldorson, Lear & Andrusiak, 1992); inferences about superordinate goals of a story character (Long, Golding, & Graesser, 1992 ; Long & Golding, 1993 ; Suh & Trabasso, 1993) ; the status of elaborative inferences on highly likely consequences of events is controversial: some authors concluded that they are not encoded (Potts, Keenan & Golding, 1988; Magliano, Baggett, Johnson, & Graesser, 1993) whereas some others claimed that they are minimally encoded (McKoon & Ratcliff, 1986) or temporally drawn and subsequently deactivated (Keefe & McDaniel, 1993). As Graesser & Kreuz (1993) pointed out, an adequate theory of inference generation should accurately predict whether particular classes of knowledge-based inferences are generated "on-line" during text comprehension" (p. 145). So, we addressed the following questions: are the inferences about likely consequences of events and actions automatically drawn while reading? How long they are activated? Did intentional and non intentional modifications of a state calls for same processes?

According to these objectives, we conducted an experiment with the main following characteristics. First, the Rapid Serial Visual Presentation procedure was used (with a 350 ms duration per word and a negligeable interword delay, see Till, Mross & Kintsch, 1988) to prevent non controlled multiple readings of parts of the sentence that was displayed (see Magliano, Baggett, Johnson, & Graesser, 1993). Secondly, a lexical decision task was used with two SOAs: 400 ms (ISI= 50 ms) and 800 ms (ISI= 450 ms) to permit the study of automatic and deliberate generation of inference. Thirdly, a question that belonged to one of the 8 following types: Who? What Object? What Property? What event/action? Where? When? How? Why?, was immediately asked after each lexical decision. Fourthly, in addition to the predictive sentence condition, a control and an explicit sentence condition were included (see appendix 1). Control sentences included the maximum of words from the predictive condition thought to be related to the inference word but did not induce the inference. Explicit sentences were identical to the predictive sentences except that the explicit sentences specified the target event/action. Finally, the Construction-Integration model proposed by Kintsch[1] (1988) was used to simulate the activation values of the propositions that composed the three forms of each sentence. By this way, the activation value of the inference proposition obtained in the Explicit, Predictive and Control conditions can be computed and compared to the experimental data (see Appendix 2).

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[1] We are grateful to Walter Kintsch for authorising us to use the Macintosh version of his Construction-Integration model of discourse comprehension written by E.F. Mross & J. O. Roberts (1991).

Hypothesis

H1a. If the inference about highly likely consequence of events and actions is automatically drawn while reading, then the decision latencies for the Explicit and the Predictable conditions would not differ and would be shorter than the decision latencies for the Control condition.

Explicit # Predictable > Control

H1b. If the inference is less activated in the Predictable condition than in the Explicit condition, then the reaction time would be longer in the Predictable condition than in the Explicit condition, while remaining shorter than in the Control condition.

Explicit > Predictable > Control

H1. If the inference is not automatically drawn while reading, the reaction times in the Predictable and the Control condition would be similar and both longer than in the Explicit condition.

Explicit > Predictable # Control

H2. If the mental representation of an intentional modification of the normal course of events involve causal ground representation and the goal of the main character, then an inference about an intentional modification of this state of affairs expressed by an action would be more likely than an inference expressed by an event and describing a non intentional modification. Consequently, the reaction time after a verb of action would be shorter than after a verb of event.

H3. If inference is automatically drawn while reading and further deactivated, we would observe an interaction between SOA and Experimental condition (Explicit, Predictive and Control). The difference between the Explicit and Predictive conditions would be longer for the long SOA (800 ms) than for the short SOA (400 ms) and the difference between the Predictive and the Control conditions would be shorter with the long SOA (800 ms) than for the short SOA (400 ms).

Method

Subjects and Design

The subjects were Fourty-eight psychology undergraduates at Paris VIII University who were divided in two groups. SOA was a between-subjects variable (400 vs. 800 ms) and sentence form a within-subjects variable (Explicit, Preditable and Control forms). The dependant variable were the decision latency and the rate of correct response.

Material

A set of sixty sentences were used (many of which have been adapted from Potts[2], Keenan, & Golding (1988) and McKoon and Ratcliff (1986)). Exemples of the sentences are shown in Appendix 1. 12 sentences were used for practice, 24 sentences were used as fillers and 24 as experimental in the experiment proper, 12 actions and 12 events .

Scaling the "compellingness" of the inferences

To measure how compellingness each inference was, an independant group of 50 subjects read the predicted condition paragraph and were asked to produce a verb that expresses the most likely consequence. The mean percentage of production of the most frequent verb was equal to 78 and 76 % for actions and events and the standard deviation was 18. In a second preliminary task, an another independant group of 50 subjects read the same sentences and chose the most highly likely consequence among the two verbs that were the most frequently chosen in the first experiment.

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[2] We are grateful to George Potts for sharing his stimulus material.

Lexical decision targets

All the inference words are verbs that were presented in the infinitive. The nonword target items were created by changing a vowel or consonant in an existing verb in order to make it a pronounceable pseudo-word and by conforming to the frequency of ending of verbs in french ("er","ir", "oir", "re").

True-False test items

A false answer to each of the eight questions per sentence was constructed by replacing the correct word or phrase by a plausible one belonging to the same semantic field (i.e., chalet vs. bungalow, wall vs. ceiling, nail vs hook, etc.).

Procedure

Upon arrival, subjects were randomly assigned to one of the two SOA conditions. Subjects worked individually on personal computers. They were instructed that they would read a series of short passages presented to them via the RSVP procedure and that they would be asked to answer a question after they read each passage. They were also instructed that they were to make a lexical decision after each sentence. They were to press a computer key marked *yes* if the lexical target was a word and a computer key marked *no* if the lexical target was not a word. They were instructed to respond quickly and accurately. The words of a sentence appeared on a screen's computer for 350 ms, with a negligeable delay between each, the final word in a sentence was always presented for 350 ms. After each sentence, there was a mask of either 50 or 450 ms, followed by a target item.

To encourage subjects to read for understanding, the target word was followed by a question about the explicit content of the sentence they had just read. The subjects chose one of the two answers that were presented by pressing the same computer keys used in the lexical decision.

Subjects received 12 pratice trials, followed by two blocks of 48 test trials.

Results

Accuracy on the comprehension questions was 95% overall and also did not vary significantly as a function of condition (all $F < 1$).

Table 1 presents the mean reaction times on correct responses for the inference words as a function of SOA and inference condition. The error rate for lexical decisions was approximately 3%. Reaction times that were more than two standard deviations from the mean of a subject's data were replaced by the value of two standard deviations above the mean.

TABLE 1: Mean lexical decision latencies and standard deviations (in ms) on correct responses as a function of inference type and SOA.

SOA	Explicit	Predictive	Control
400 ms (ISI=50 ms)	759 *(91)*	818 *(106)*	875 *(109)*
800 ms (ISI=450 ms)	676 *(64)*	718 *(63)*	751 *(85)*

The mean latencies were analyzed in ANOVA with inference condition (Explicit, Predictive, or Control) and nature of the modification (action vs event) as within-subjects factors and SOA (400 vs. 800 ms) as a between-subjects factor. The two analyses that were performed, one using subjects as the random variable and one using stimulus items as the random variable, gave similar results.

The main effect of Inference condition was significant [$F(2, 116) = 87{,}592$, $p < .01$], with the Explicit producing faster responding than the Predictive [$F(1, 116) = 49{,}074$, $p < .01$] that, in turn, produced faster responding than the Control [$F(1, 116) = 38{,}722$, $p < .01$]. It would appear, therefore, that the causal consequences were generated on-line. The main effect of SOA was also significant [$F(1, 58) = 27{,}903$, $p < .01$], with the long SOA producing faster responses than the short

SOA: 818 vs 715 ms. A significant interaction Inference Condition * SOA was obtained [$F(2, 116) = 4{,}061$, $p < .05$]. The two degrees of freedom were decomposed by comparing Explicit vs. Predictive conditions and Predictive vs. Control conditions. The difference between the Explicit and Predictive conditions was greater for the short SOA: 59 vs 42 ms, respectively ; and the difference between the Predictive and Control conditions was greater for the short SOA than for the long SOA: 57 vs 33 ms, respectively. It is possible to infer from this result that the causal inference began to decline with a SOA equal to 800 ms. Finally, the decision latencies of inferences expressed by an action were significantly faster than the decision latencies of inferences expressed by an event: 757 vs 776 ms, [$F(1, 58) = 15{,}544$, $p < .01$].

Discussion

If lexical decision provides an appropriate test of on-line inferencing, then the present results would suggest that inferences about the likely consequences of events and actions are drawn while reading. The hypothesis proposed by Potts & al. (1988) by which "lexical decision may also involve backward context-checking at the time of test" (p. 414) is inconsistent with the results obtained by Keefe & al. (1993) who find evidence for forward inferencing (experiments 2 & 3) by using a naming task. How can we explain theses discrepancies? We can assume that causal consequences are generated on-line when the context is highly constrained by the passage content and word knowledge (i.e., only one or two outcomes are possible) or by the depth of processing asked to the reader.

Another problem lies in the time course of activation of causal inferences. Our results are not conclusive from this point of view and longer SOAs had to be used in the future (see Till & al., 1988) and related to precise analysis of text comprehension (Kintsch, 1988 ; Magliano & al., 1993).

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Appendix 1

Example of action (adapted from Potts, Keenan & Golding, 1988, paragraph 23)

Explicit:

French: Les contractions se faisant de plus en plus fréquentes, la femme qui venait de terminer un travail pénible, se rendit à la maternité **et accoucha**.

English: The contractions becoming more and more frequent, the woman who just finished a hard labor, went to the maternity hospital **and delivered**.

Predictive:

French: Les contractions se faisant de plus en plus fréquentes, la femme qui venait de terminer un travail pénible, se rendit à la maternité.

English: The contractions becoming more and more frequent, the woman who just finished a hard labor, went to the maternity hospital.

Control:

French: Lorsqu'elles arrivent à la soixantaine, les femmes qui ont eu de nombreuses maternités et qui ont exercé des travaux pénibles, souffrent de plus en plus fréquemment de contractions musculaires.

English: When they are in their sixties, the women who had numerous pregnancies and had hard labor, suffered more and more frequently from muscular contractions.

Inference test word: French: accoucher, **English:** to deliver

Example of event

Explicit:

French: Le commandant de bord allait demander aux hôtesses d'annoncer aux passagers la traversée d'une zone de forte turbulence quand l'avion piqua brusquement vers le sol **et s'écrasa**.

English: The captain was about to ask to the hostesses to announce to the passengers that they will pass trough a zone of strong turbulence when the plane suddenly go down to the ground **and crashed.**

Prédictive:

French: Le commandant de bord allait demander aux hôtesses d'annoncer aux passagers la traversée d'une zone de forte turbulence quand l'avion piqua brusquement vers le sol.

English: The captain was about to ask to the hostesses to announce to the passengers that they will pass trough a zone of strong turbulence when the plane suddenly go down to the ground and **crashed.**

Control:

French: Les hôtesses, excédées par la turbulence des passagers de l'avion, informèrent le commandant de bord qui piqua une colère et fit brusquement une annonce.

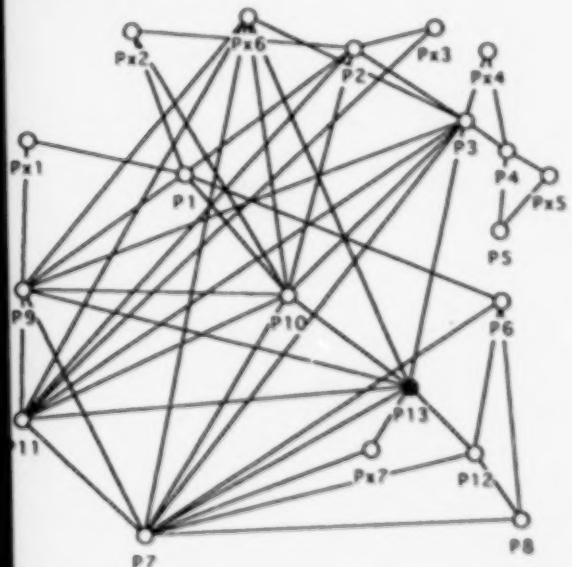
English: The air hostesses, who were exasperated by the turbulence of the passengers', informed the captain who threw a fit and suddenly advertise the passengers.

Inference test word: French: s'écraser, **English:** to crash.

Final activation values of the propositions of the text base of the 3 forms of the "Captain" passage.

Px1 c1 0.2040 Captain
Px2 c1 0.2989 Hostesses
Px3 c1 0.2181 Passengers
Px4 c1 0.1633 Zone
Px5 c1 0.0302 Turbulence
Px6 c1 0.8285 Plane
Px7 c1 0.2755 Ground
P1 c1 0.4800 TOASK[Px1,Px2,P2]
P2 c1 0.5652 TOANNOUNCETO[Px2,Px3,P3]
P3 c1 0.9436 TOPASSTHROUGH[Px6,Px4]
P4 c1 0.1715 OF[Px4,Px5]
P5 c1 0.0302 STRONG[Px5]
P6 c1 0.3002 WHEN[P1,P7]
P7 c1 0.9778 TOGODOWN[Px6,Px7]
P8 c1 0.2389 SUDDENLY[P7]
P9 c1 0.9158 INF:PARTOF[Px1,Px6]
P10 c1 1.0000 INF:PARTOF[Px2,Px6]
P11 c1 0.9283 INF:PARTIEOF[Px3,Px6]
P12 c1 0.3547 CONSEQ:AND[P7,P13]
P13 c1 0.9089 TOCRASH[Px6,Px7]

Criterion: 0.0010
Delta: 0.0007
Iterations: 7

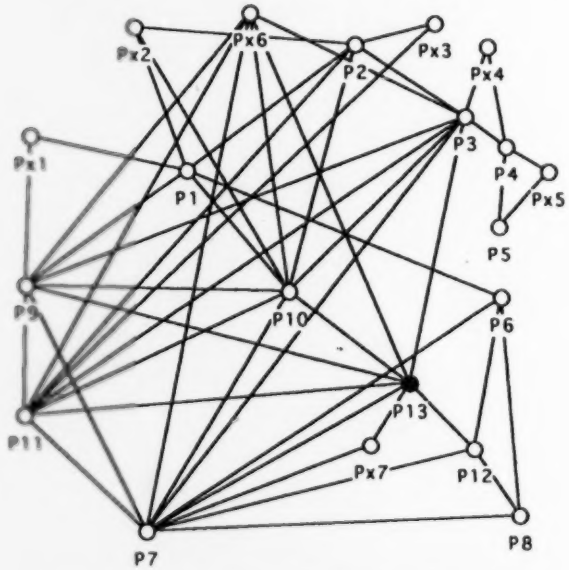


"Captain". Explicit Form.
Argument Overlapping.

Starting activation value = 1

Px1 c1 0.2040 Captain
Px2 c1 0.2992 Hostesses
Px3 c1 0.2184 Passengers
Px4 c1 0.1630 Zone
Px5 c1 0.0297 Turbulence
Px6 c1 0.8283 Plane
Px7 c1 0.2751 Ground
P1 c1 0.4800 TOASK[Px1,Px2,P2]
P2 c1 0.5656 TOANNOUNCETO[Px2,Px3,P3]
P3 c1 0.9433 TOPASSTHROUGH[Px6,Px4]
P4 c1 0.1708 OF[Px4,Px5]
P5 c1 0.0297 STRONG[Px5]
P6 c1 0.2990 WHEN[P1,P7]
P7 c1 0.9766 TOGODOWN[Px6,Px7]
P8 c1 0.2377 SUDDENLY[P7]
P9 c1 0.9156 INF:PARTOF[Px1,Px6]
P10 c1 1.0000 INF:PARTOF[Px2,Px6]
P11 c1 0.9284 INF:PARTIEOF[Px3,Px6]
P12 c1 0.3534 CONSEQ:AND[P7,P13]
P13 c1 0.9083 TOCRASH[Px6,Px7]

Criterion: 0.0010
Delta: 0.0005
Iterations: 8

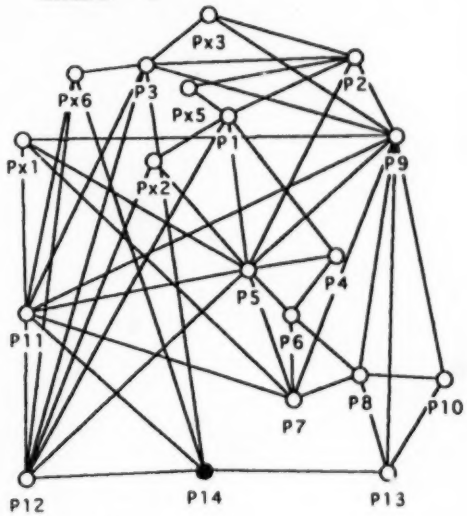


"Captain". Predictive Form.
Argument Overlapping.

P12 & P13: Starting activation value = 0

Px1 c1 0.5868 Captain
Px2 c1 0.3671 Hostesses
Px3 c1 0.3821 Passengers
Px5 c1 0.1854 Turbulence
Px6 c1 0.4792 Plane
P1 c1 0.5230 EXASPERATEDBY[Px2,Px5]
P2 c1 0.6204 OF[Px5,Px3]
P3 c1 0.7561 PARTOF[Px3,Px6]
P4 c1 0.3116 INF:CAUSE[P1,P5]
P5 c1 1.0000 TONFORM[Px2,Px1,P2]
P6 c1 0.3986 INF:CONSEQ[P5,P7]
P7 c1 0.7042 TOTHROWAFIT[Px1]
P8 c1 0.4438 AND[P7,P9]
P9 c1 0.9845 TOANNOUNCE[Px1,Px3]
P10 c1 0.2900 SUDDENLY[P9]
P11 c1 0.9357 AND[Px1,Px6]
P12 c1 0.7428 AND[Px2,Px6]
P13 c1 0.3637 AND[P9,P14]
P14 c1 0.5298 TOCRASH[Px6]

Criterion: 0.0010
Delta: 0.0006
Iterations: 9



"Captain". Control Form.
Argument Overlapping.

P12 & P13: Starting activation value = 0

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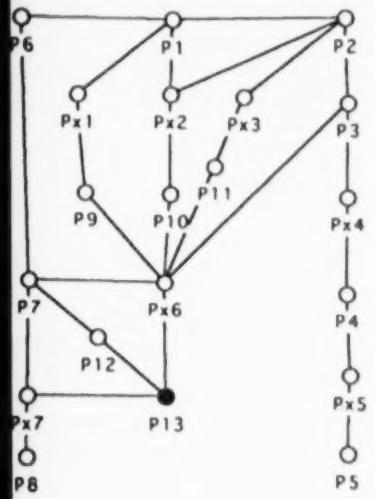
Note: Inference proposition is underlined.

Appendix 2b

Final activation values of the propositions of the text base of the 3 forms of the "Captain" passage.

Px1 c1 0.3200 Captain
Px2 c1 0.5472 Hostesses
Px3 c1 0.3359 Passengers
Px4 c1 0.2088 Zone
Px5 c1 0.0288 Turbulence
Px6 c1 1.0000 Plane
Px7 c1 0.4471 Ground
P1 c1 0.6062 TOASK[Px1,Px2,P2]
P2 c1 0.6514 TOANNOUNCETO[Px2,Px3,P3]
P3 c1 0.5844 TOPASSTHROUGH[Px6,Px4]
P4 c1 0.0764 OF[Px4,Px5]
P5 c1 0.0100 STRONG[Px5]
P6 c1 0.4123 WHEN[P1,P7]
P7 c1 0.7087 TOGODOWN[Px6,Px7]
P8 c1 0.1399 SUDDENLY[P7]
P9 c1 0.4137 INF:PARTOF[Px1,Px6]
P10 c1 0.4851 INF:PARTOF[Px2,Px6]
P11 c1 0.4188 INF:PARTIEOF[Px3,Px6]
P12 c1 0.4033 CONSEQ:AND[P7,P13]
P13 c1 0.5795 TOCRASH[Px6,Px7]

Criterion: 0.0010
Delta: 0.0007
Iterations: 11

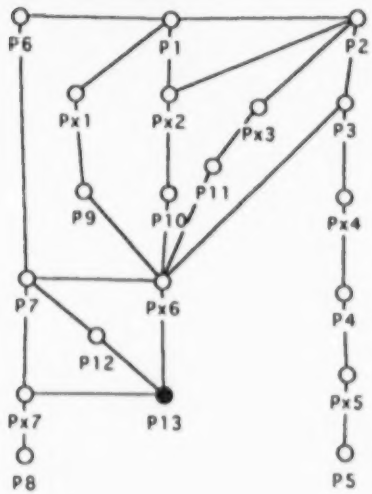


"Captain". Explicit Form.
Minimal Predication.

Starting activation value = 1

Px1 c1 0.3227 Captain
Px2 c1 0.5526 Hostesses
Px3 c1 0.3385 Passengers
Px4 c1 0.2071 Zone
Px5 c1 0.0259 Turbulence
Px6 c1 1.0000 Plane
Px7 c1 0.4449 Ground
P1 c1 0.6122 TOASK[Px1,Px2,P2]
P2 c1 0.6571 TOANNOUNCETO[Px2,Px3,P3]
P3 c1 0.5853 TOPASSTHROUGH[Px6,Px4]
P4 c1 0.0735 OF[Px4,Px5]
P5 c1 0.0083 STRONG[Px5]
P6 c1 0.4139 WHEN[P1,P7]
P7 c1 0.7074 TOGODOWN[Px6,Px7]
P8 c1 0.1389 SUDDENLY[P7]
P9 c1 0.4147 INF:PARTOF[Px1,Px6]
P10 c1 0.4872 INF:PARTOF[Px2,Px6]
P11 c1 0.4197 INF:PARTIEOF[Px3,Px6]
P12 c1 0.4016 CONSEQ:AND[P7,P13]
P13 c1 0.5775 TOCRASH[Px6,Px7]

Criterion: 0.0010
Delta: 0.0009
Iterations: 16

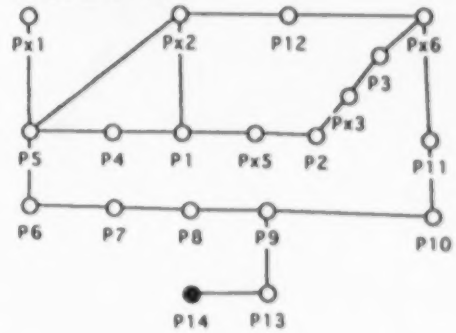


"Captain". Predictive Form.
Minimal Predication.

P12 & P13: Starting activation value = 0

Px1 c1 0.3952 Captain
Px2 c1 0.9185 Hostesses
Px3 c1 0.1825 Passengers
Px5 c1 0.4135 Turbulence
Px6 c1 0.3765 Plane
P1 c1 0.8093 EXASPERATEDBY[Px2,Px5]
P2 c1 0.2362 OF[Px5,Px3]
P3 c1 0.2227 PARTOF[Px3,Px6]
P4 c1 0.7150 INF:CAUSE[P1,P5]
P5 c1 1.0000 TONFORM[Px2,Px1,P2]
P6 c1 0.5009 INF:CONSEQ[P5,P7]
P7 c1 0.2663 TOTHROWAFIT[Px1]
P8 c1 0.1702 AND[P7,P9]
P9 c1 0.1596 TOANNOUNCE[Px1,Px3]
P10 c1 0.1487 SUDDENLY[P9]
P11 c1 0.2101 AND[Px1,Px6]
P12 c1 0.5133 AND[Px2,Px6]
P13 c1 0.0774 AND[P9,P14]
P14 c1 0.0315 TOCRASH[Px6]

Criterion: 0.0010
Delta: 0.0010
Iterations: 25



"Captain". Control Form.
Minimal Predication.

P12 & P13: Starting activation value = 0

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Note: Inference proposition is underlined.